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A MICROWAVE INTERFEROMETER SYSTEM FOR HUMIDITY MEASUREMENT

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Abstract

A microwave interferometer system for humidity measurement has been developed. The system is based on the sensitivity of the air permittivity to the water vapor content and offers a faster response and a better air pollution insensitivity with respect to the traditional humidity sensors which are based on hygroscopic substances. Experimental results show the effectiveness of the new approach in the range of 20%RH to 70%RH.

Summary

Humidity measurement has become an important task in many fields, such as food, paper and chemical industries, research laboratories and climatic conditioning systems. Furthermore, most quality standards and calibration procedures require the knowledge of the environmental relative humidity. The commercially available sensors are usually based on the sensitivity of hygroscopic substances electrical parameters to the humidity [1,2]. Such sensors are reasonably accurate and cheap, but their measurement uncertainty abruptly increases after exposures to air pollution, so that a new calibration procedure is required. Moreover the water vapor diffusion that takes place in the hygroscopic substances requires a long time interval to be completed and suffers from hysteresis phenomena.
In the past a microwave cavity oscillator was used as sensor and its frequency vs. humidity measured [3].
This paper describes a microwave interferometer technique to measure the air permettivity sensitivity to the water vapor content. The basic idea is the measurement of the electrical length's change due to humidity of an holed circular waveguide. The system, shown in figure 1, is based on a circular waveguide with proper holes as test path and a coaxial cable as reference path.
The waveguide length is 35 cm and its diameter of 12.9 mm. In order to allow the fundamental mode propagation only, the working frequency has been set at 18.45 GHz, which also corresponds to a return loss minimum of the waveguide to coaxial transitions.

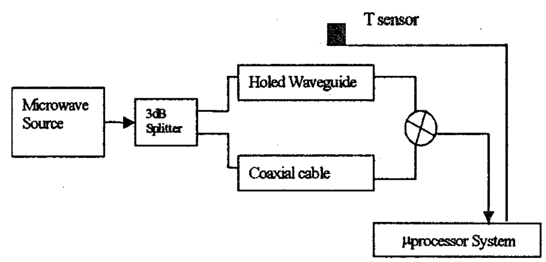

Figure 1: Microwave Humidity measurement

As well know the DC output voltage of the mixer is proportional to the two path electrical length difference thus, after a proper calibration, the microprocessor based acquisition system can directly compute the relatively humidity.
The measurement system also embeds a temperature sensor, because this quantity influences the mixer voltage output due to thermal dependence of both the air permettivity and the waveguide geometrical parameters. Through a temperature calibration the microprocessor system takes the temperature data into account.
The simulation of the developed system model proved a humidity standard uncertainty of 1%RH by measuring the mixer output voltage with a relative uncertainty of $2\cdot10^{-3}$ and the temperature with a standard uncertainty of 0.05 C°.
Experimental results have been performed inserting the waveguide, the temperature sensor and a reference humidity sensor into a climatic chamber for a long test run.
Figure 2 shows the raw mixer output voltage, the humidity content measured with a reference sensor and the chamber temperature during the test. The output voltage changes well track the humidity behavior without any post processing on the signals.
Once the calibration is taken into account and the developed system model applied the plot of figure 3 is obtained.

Here the compute humidity from the proposed system and the reference sensor measurement are plotted vs the time test period.
The discrepancy of the obtained results is of few percent in the overall measurement range, from 20%RH to 70%RH, which testify the validity of this microwave system and of the applied calibration model.
The authors are currently working on a more practical solution based on a microstrip realization at lower microwave frequency in order to decrease the system cost. More results will be given at the conference time.

References

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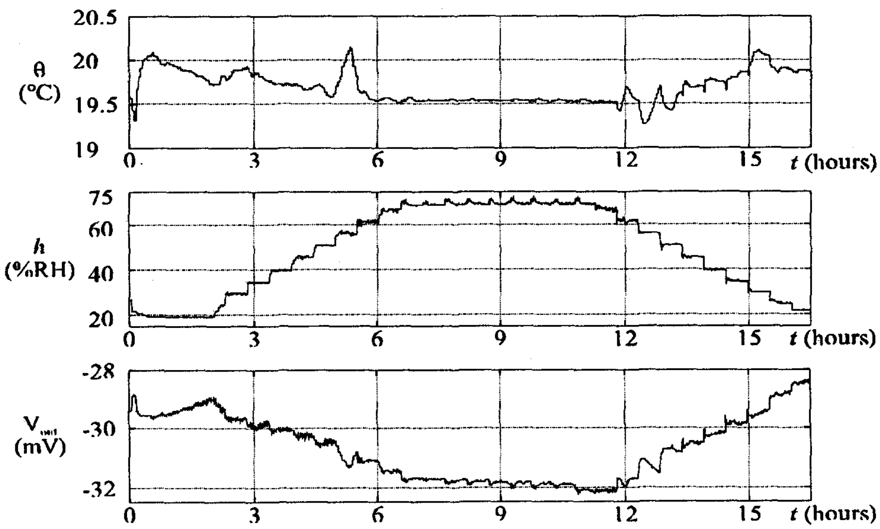

Figure 2: Temperature, Humidity and Mixer raw output voltage during the climate chamber test

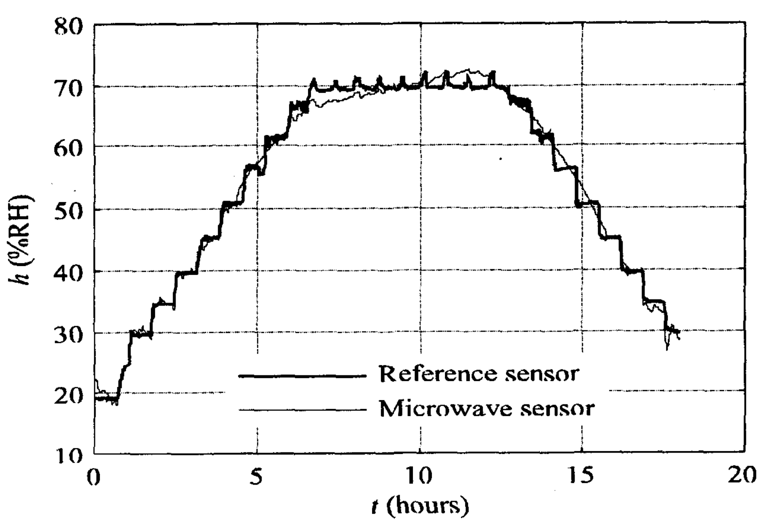

Figure 3: Comparison between the reference humidity sensor and the proposed microwave system